A Study of the Effects of Strip-Mining on the Water Composition of Cross Creek in West Virginia and Pennsylvania.

Thesis

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by

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Abstract

Strip mine runoff has long been known to have detrimental effects on local surface water quality. The Cross Creek drainage area can be divided into an upper portion largely unaffected by strip mine activity and a lower portion in which several major tributaries run directly through abandoned mines to feed the creek. Essentially all the heavy mining of the area adjacent to the creek and within its drainage basin ceased approximately 10 years ago. A study of several selected elements contained in water samples from areas both above and below the mines, as well as other parameters, indicates that the Cross Creek area has nearly completely recovered from the effects of mining. Analysis was also made for toxic trace metals as part of a water quality study and significant concentrations were not detectable.

Introduction

What are the effects of strip-mine runoff after an extensive period of inactivity on a stream system? Cross Creek provided a suitable setting to answer such a question. The lower portion of the creek flows through a mined out area while the upper part is largely unaffected by mining activity. By comparing the trace element concentration of water samples from the two parts of the creek the effects of mining, if there were any, could be easily determined.

The path of Cross Creek can be followed in the Avella and Stuebenville East 7.5' quadrangles. This paper is organized into a general physiography and bedrock geology section in which evidence of the expected source of much of the materials analysed for is found. Following this is a description of the analytical techniques used, which involved primarily the use of the atomic absorption unit. The paper then concludes with an analysis and discussion of the data as regards the effects of mining and water quality.

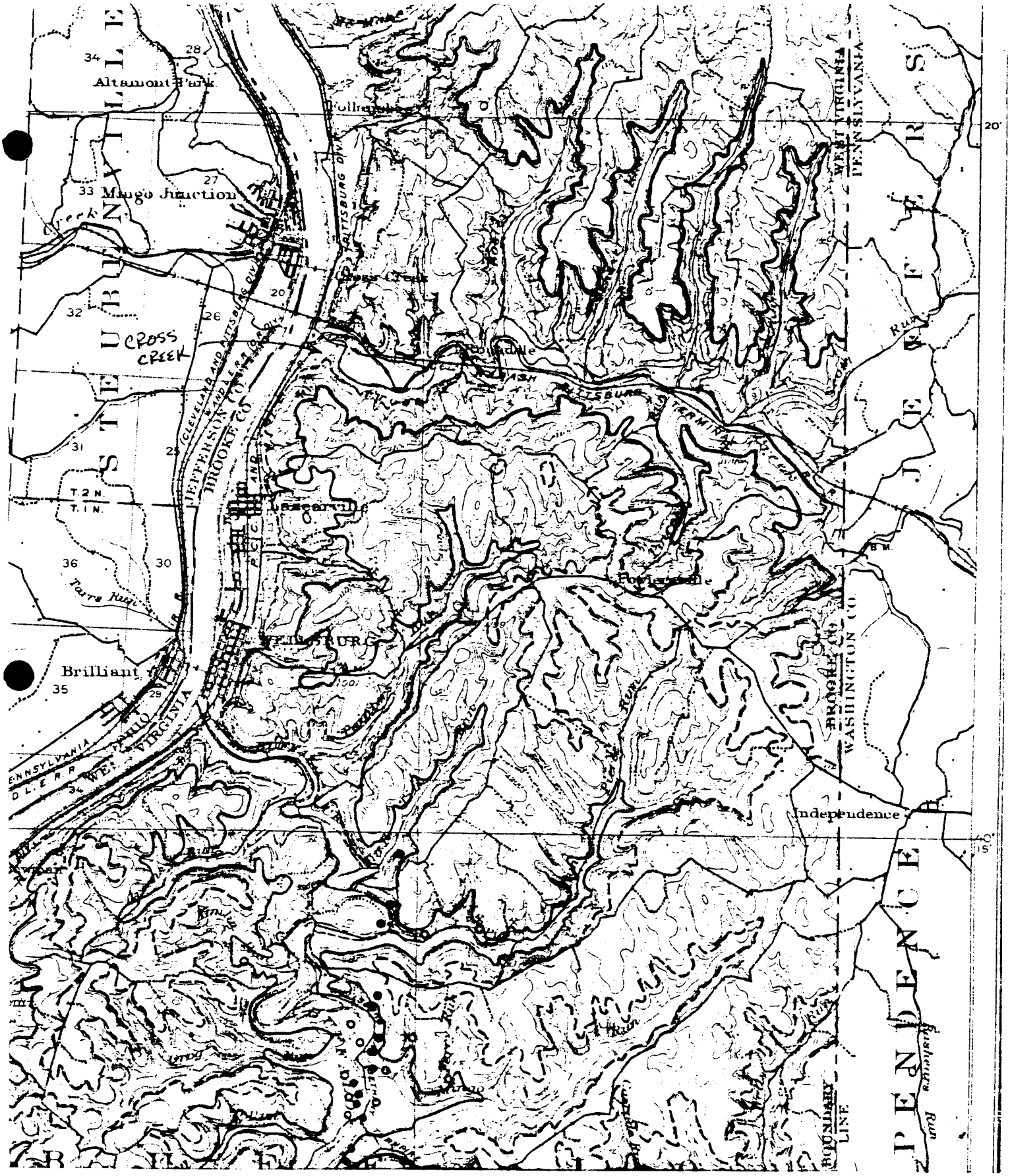


Fig. 1

Map showing the path of Cross Creek through the panhandle of West Virginia. Heavy line is Pittsburgh coal

Physiography

The Cross Creek drainage area is a part of the Ohio River Basin and lies within the Kanawha section of the Appalachian Plateau. The major length of the creek runs through Brooke County, West Virginia in the panhandle area of the state. The panhandle is a mature, highly dissected plateau of fine texture and is approximately 1200 feet in elevation (Fenneman, 1940). Cross Creek enters this area from Washington County, Pennsylvania and follows a course almost due west in a winding channel which has a gradient of approximately 17 feet per mile (Grimsely, 1907).

In the panhandle, the creek is fed by four major runs named, from the north, Bosley, Ebenezer, and Parmar and Potrock from the south. From Avella, Pennsylvania in Washington County to the Ohio River the terrain adjacent to the creek has been extensively strip mined, primarily for the Pittsburgh Coal (see fig. 1). In Washington county, just east of Avella the creek is fed by three forks named the North, Middle and the South. From the point of convergence of these three forks to the mouth of the creek at the Ohio River a distance of approximately 7.5 miles is traversed. The total drainage area of the creek is about 40 sq. miles

The panhandle area was not directly glaciated as it appears that the most recent glaciations stopped a few miles north of the Ohio Valley. However, large amounts of rock debris were deposited in the major valleys by outwash streams.

Bedrock Geology

The sequences of rock in the Cross Creek area as well as those of the Ohio Valley are nearly horizontal and relatively undisturbed. This region is a part of the Dunkard Basin which is split from northeast to southwest by the Ohio River and transversly near the middle by the Burning Springs anticline (Cross, Schemel, 1956).

Rocks outcropping along Cross Creek range in age from Upper Pennsylvanian to Lower Permian and include the Conemaugh, Monongahela and Dunkard Groups (see fig. 2). The rocks are virtually all fresh water deposits, excluding the Ames Limestone member of the Glenshaw Formation in the Conemaugh Group, and consist primarily of sandstones and limestones with many coal beds. A brief description of the groups and their formations follows, including information on ground water yield (see table 1).

The Conemaugh Group:

The Conemaugh Group is Upper Pennsylvanian in age and is divided into two formations, the Glenshaw and the Casselman. The Glenshaw Formation is about 30.5 meters in thickness and is composed mostly of mudstone containing thin to medium beds of siltstone and sandstone. The Casselman Formation is composed primarily of variegated mudstone and claystone containing thin to medium beds of siltstone and fine to medium grained sandstone. The thickness of the formation is approximately 67 meters. The ground-water yield of the group ranges from 1 to 50 gpm with a median yield of

5 gpm (Newport, 1973).

The Monongahela Group:

This group consists of two formations, the Pittsburgh and the Uniontown. The Pittsburgh Formation is between 70 and 82.3 meters in thickness and is subdivided into five members. The formation is composed primarily of interfingering beds of limestone, shale and mudstone with locally massive sandstone. In this formation is found the Pittsburgh Coal, previously mentioned, which was removed in great quantity from the areas adjacent to Cross Creek (see fig. 1). The Uniontown Formation ranges in thickness from 13.7 to 16.7 meters. Like the Pittsburgh, it too is divided into members although there are only two of them. The Uniontown Formation is mostly mudstone containing thin beds of siltstone and sandstone. The boundary between the Uniontown and the Pittsburgh is marked by the Uniontown coal bed. Ground-water yields for this group range from 0.1 to 50 gpm with a median yield of 2gpm.

The Dunkard Group:

The lowest formation of the Dunkard is of Upper Pennsylvanian and Lower Permian age and is named the Waynesburg Formation. The other formations of the group include the Washington and the Greene, both of which are Lower Permian in age. The Waynesburg Formation has a thickness of between 26 and 36.5 meters. It is composed mostly of mudstone with interfingering beds of shale and siltstone. The Waynesburg coal bed is located at the base. The Washington Formation is between 48 and 61 meters thick and consists of alternating beds of shale and sandstone and several coal beds. Also found

within the formation are several thin-bedded discontinuous limestone members. The ground-water yield of the Washington Formation ranges from 1 to 70 gpm with a median yield of 2 gpm. The Greene Formation is poorly exposed in the Cross Creek area and its lithology has been referred to as composed of the Fishcreek Sandstone and the Donely Limestone members and associated beds. The unit is composed of sandstone that grades laterally into thin-bedded shaly limestone and encloses several discontinuos thin shaly beds of limestone. The ground-water yield of the Greene Formation is from less than 1 to 35 gpm with a median yield of 2 gpm.

Quaternary Holocene and Pleistocene	Alluvium	0-63	Well to poorly sorted deposits of clay, sand, gravel and cobbles.	Yields generally large, depending upon degree of sorting by grain size.
Permian	Greene Formation	61-260	Shale and shaly sandstone, a few thin limestone beds, and thin coal beds; much red shale in lenticular beds.	Moderate yields from sandstone; small yields from shale bedding-plane openings.
Permian – Pennsylvanian	Washington Formation	36-304	Alternating layers of shale and fine-grained sandstone, thin-bedded limestone and several coal beds.	Sandstone members are best producers. Rest of formation is a poor producer.
Pennsylvanian	Monongahela Group	48-397	Limestone beds of variable thickness, discontinuous sandstone beds, and several coal beds.	Limestone beds yield moderate water supplies from joints and bedding planes. Sandstone beds are less productive. Not water-bearing beneath thick cover.
	Conemaugh Group	44-438	Gray, green and red shale with discontinuous sandstone beds, some thin limestone beds and coal; all members variable in thickness.	Water-yielding capacity ranges greatly from place to place. Sandstones are best producing beds.

Table 1

Generalised description of bedrock geology in the Cross Creek area (Newport, 1973)

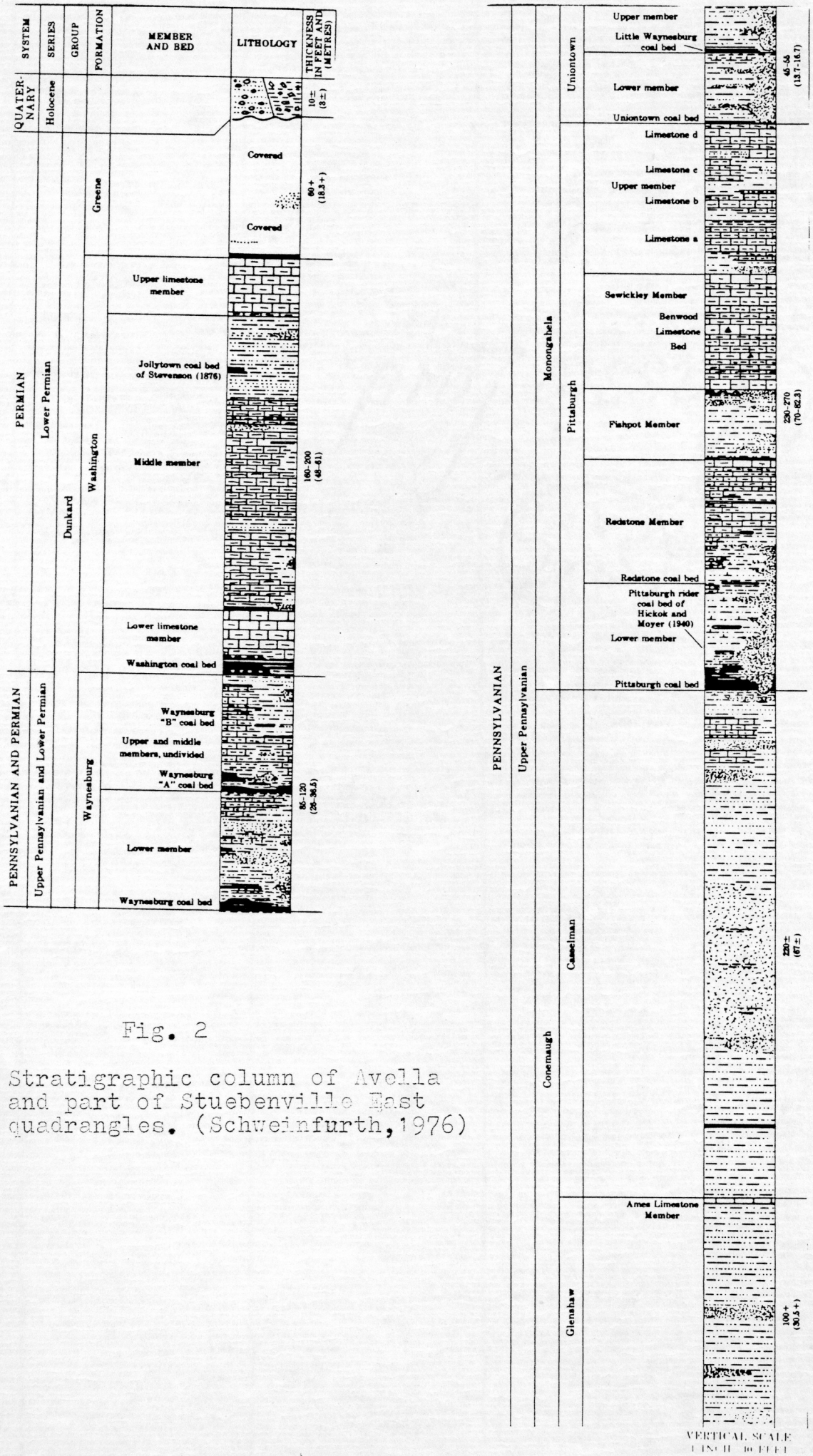


Fig. 2

Stratigraphic column of Avella and part of Steubenville East quadrangles. (Schweinfurth, 1976)

Sample Analysis

Water samples were collected at eight locations along Cross Creek (see fig. 3). Field measurements of conductivity and PH were made at each of the sample locations. The samples were collected on March 20, 1982, placed in plastic bottles, and returned to the laboratory.

Using a Perkins-Elmer atomic absorption spectrophotometer analysis of the samples was undertaken for the elements calcium, sodium, magnesium, iron, cadmium, lead and mercury. The photometer consists of basically a light source, an atomizer, a wavelength selector and a detector-readout system. The sample to be analysed is introduced to the machine in an aqueous form. By means of the atomizer, which is a burner utilizing an air-acetylene flame, the molecules in the sample are dissociated into their constiuent atoms. The flame however is not hot enough to excite the atoms and as a result they remain in their neutral ground state. A monochromatic light source which is provided by means of a hollow cathode ray tube, of the elements whose detection is desired, is then passed through the flame. If the desired element is present a certain amount of the light will be absorbed by the atoms in relation to their abundance in the sample. The wavelength selector then seperates the desired resonance lines from the other emission lines of the source. These isolated wavelengths are then passed on to a transducer which converts the incident radiation of the wavelength to an electric signal related to intensity.

A linear relationship exists between concentration and peak absorbance of the atoms. By comparing the absorbance of known ref-

erence standards, run under the same conditions as the unknowns, the concentrations of the unknowns can be determined. Absorbance was recorded by means of a strip chart (see fig. 4) which gives a peak height in relation to concentration. A linear graph is prepared, using the reference standards, which plots concentration verses peak height as measured by the recorder (see fig. 5). The sample concentration can then be measured by comparing peak heights on the graph. It is necessary that the sample concentrations fall within the linear portion of the graph. For this reason several of the sample unknowns were diluted. It is also important to note that the wavelength selector on the particular machine I used read about 4A low. This is reflected in the machine setting data that follows in the individual element analysis.

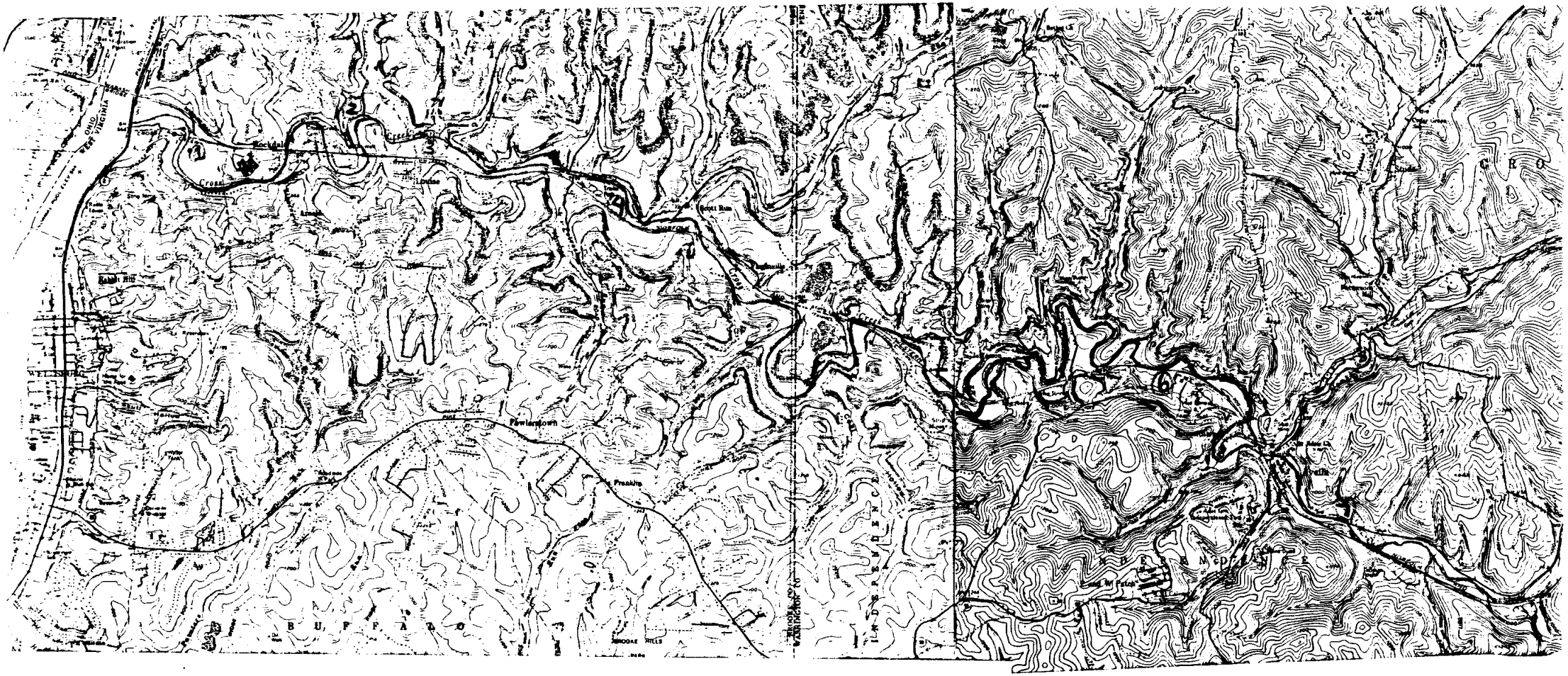
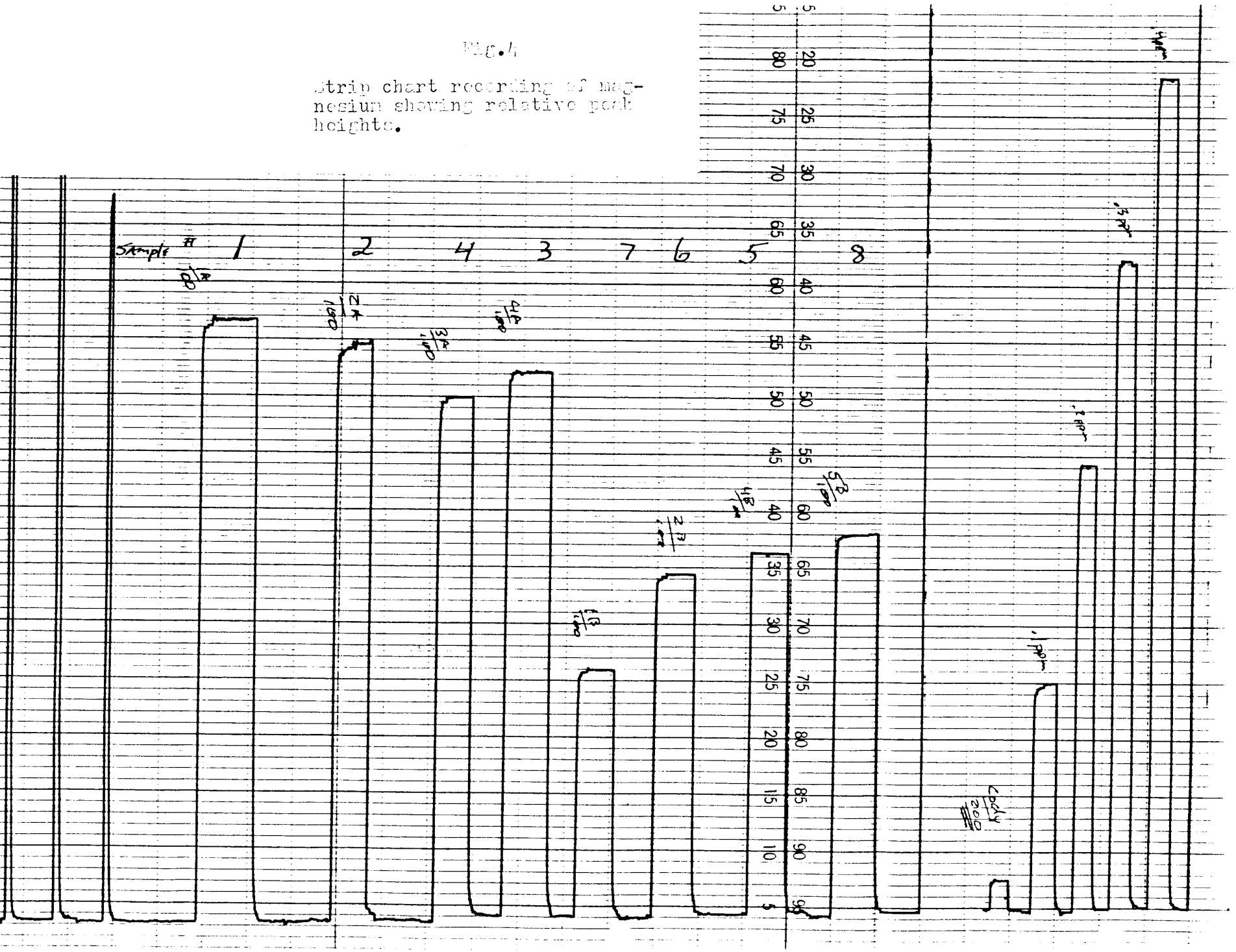


Figure 3: Sample collection locations

Fig. 4

Strip chart recording of magnesium showing relative peak heights.



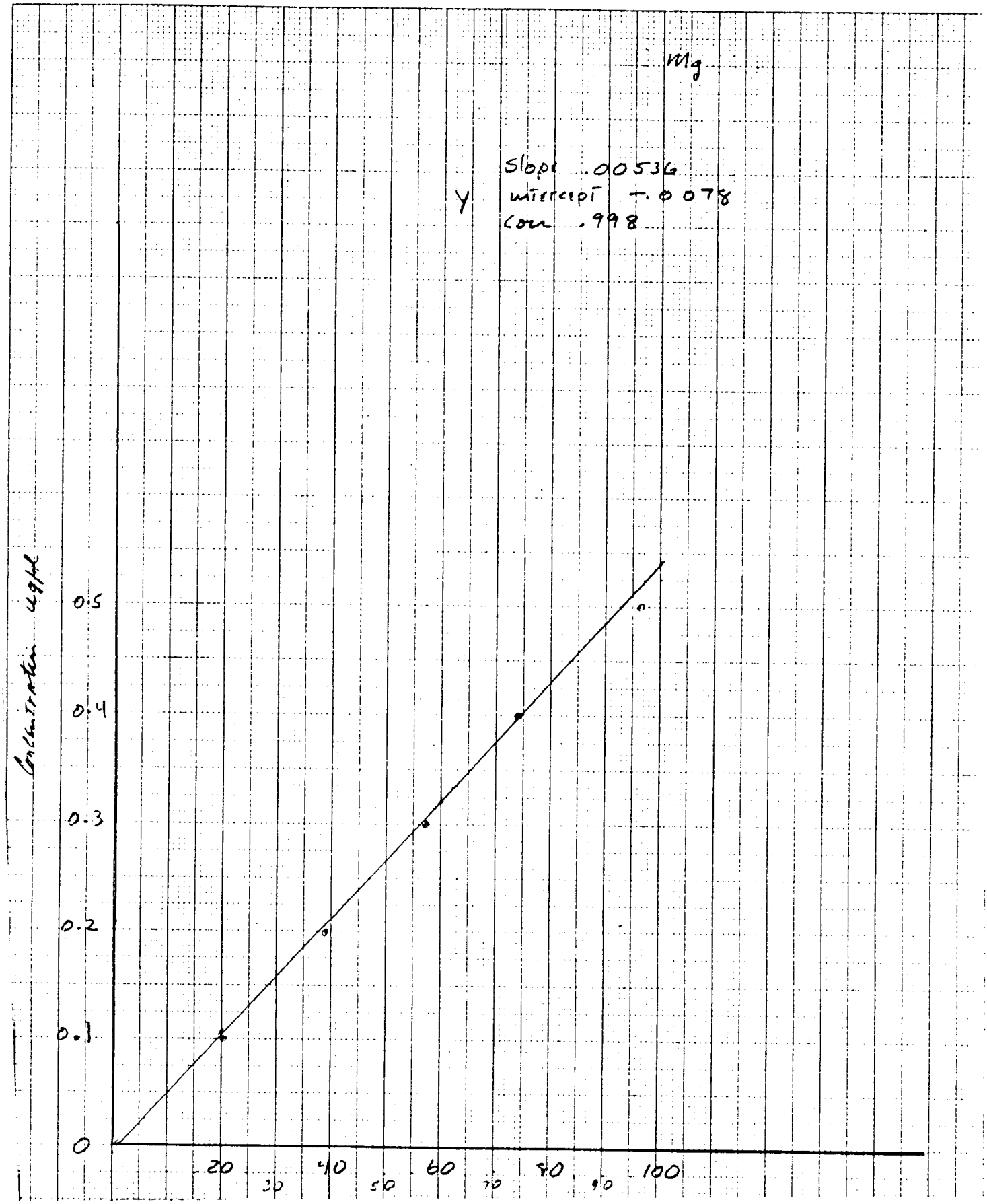


Fig. 5

Graph of the relationship between peak ht. and contration as determined by reference standards.

Calcium

Reagents :

Ca, 500 ug/ml. To 1.249 g of primary standard calcium carbonate, $CaCO_3$, add 50 ml of demineralized water. Add dropwise a minimum volume of HCl (app. 10 ml) to effect complete solution of the $CaCO_3$. Dilute to 1 liter with deionized water.

This stock solution of 500 ppm was then further diluted to give five standards of concentrations 1, 2, 3, 5 and 7 ppm. Samples were then diluted 15x to make them fall within the linear range for calcium.

Machine settings:

Meter response	1
Scale	1
Source	16
Slit	4
Range	VIS 2090 A

Sample	Concentration (ppm)
1	195.25
2	186.59
3	181.17
4	177.93
5	135.69
6	135.69
7	140.03
8	129.20

Magnesium

Reagents:

Mg, 1000 ug/ml. Dissolve 1.0 g of magnesium ribbon in a minimum volume of (1+1) HCl. Dilute to 1 liter with 1% (v/v) HCl.

From this stock solution standards of concentrations 0.1, 0.2, 0.3, 0.4 and 0.5 ppm were prepared. Samples were then diluted 100x and concentrations were determined.

Machine settings:

Meter response	1
Scale	1
Source	16
Slit	4
Range	UV 2827 A

Sample	Concentration (ppm)
1	27.63
2	26.42
3	24.95
4	24.01
5	16.24
6	15.43
7	11.01
8	17.17

Sodium

Reagents:

Na, 1000 ug/ml. Dissolve 2.542 g of sodium chloride, NaCl in 1 liter of deionized water.

Standards were prepared from this stock solution in the following concentrations: 0.1, 0.3, 0.5, 0.7 and0.9 ppm. The sample unknowns were diluted 30x to bring them within the linear range for sodium.

Machine settings:

Meter response	1
Scale	1
Source	16
Slit	4
Range	VIS 2918 A

Sample	Concentration (ppm)
1	12.41
2	12.53
3	12.57
4	12.06
5	12.04
6	13.02
7	7.07
8	9.69

Iron

Reagents:

Fe, 1000 ug/ml. Dissolve 1.000 g of iron wire in 50 ml of (1+1) HNO_3. Dilute to 1 liter with deionized water.

From this stock solution standards of concentrations 0.5, 1.5, 2.5, 4.0 and 5.0 ppm.were prepared. As the concentration of the iron in the unknowns was so small there was no need to dilute the samples.

Machine settings:

Meter response	1
Scale	1
Source	16
Slit	4
Range	UV 2461 A

Sample	Concentration (ppm)
1	0.160
2	0.130
3	0.173
4	0.173
5	0.105
6	0.144
7	0.082
8	0.118

Sample	Ca	Mg	Na	Fe	Conductivity (MICROMHOS/CM³)	PH	Temp °C
1	195.25	27.63	12.41	0.160	590	8.58	8.8
2	186.59	26.42	12.53	0.130	610	8.50	9.0
3	181.17	24.95	12.57	0.173	600	8.20	8.9
4	177.93	24.01	12.06	0.173	600	8.50	8.5
5	135.69	16.24	12.04	0.105	525	8.60	8.6
6	135.69	15.14	13.02	0.144	420	8.70	8.8
7	140.03	11.01	7.07	0.082	390	9.10	8.7
8	129.20	17.17	9.69	0.118	400	8.60	8.9

Table 2

Cumulative data for the eight samples

Discussion of results

It is immediately apparent upon examining the concentrations of calcium, magnesium and conductivity that a significant break in the data exists. This break occurs between stops 4 and 5 or between the heavily mined areas and those that are generally above the mining (see table 2). Stop 5 is within the mine portion but occurs before the four principle runs which go through the empty mines into the creek. Another factor that is important is the distance between stops 4 and 5 which is greater than any other sample locations. Once, however, sample data are observed within the run area there is no significant increase from one run to the other. This indicates that the new influx of material is coming mostly from Scott and Parmer Runs which discharge into Cross Creek at the same location. Beyond these runs, in a downstream direction, there is no significant break in the data but rather a slight expected increase in the concentrations of Ca and Mg.

The specific conductance is a measure of the ability of a solution to conduct an electrical current. The ability to conduct a current is dependant upon the amount of ionized salts in the solution. The conductivity can therefore be used to give an approximate amount of the total dissolved solids in the solution. Using the formula; D.S. (mg/l)=conductivity (micromhos/cm^3)x 2/3 and the value of 600 for the conductivity it is found that dissolved solids in the creek are approximately 400 mg/ml. This value is not extreme as the tolerable amount of dissolved solids in drinking water should not exceed 500 ppm. It is therefore evident that there is not an excessive amount of dissolved solids entering the Cross Creek.

As was mentioned previously, the area around Cross Creek was mined primarily for the Pittsburgh coal, a coal which has a high acid producing potential (APP) (see table 3). The APP is a relative indicator expressed in reference to the other coals of West Virginia. These numbers are derived from experiments involving leached material from the fresh faces of coal samples. It is generally accepted that acid is the result of the dissolution of pyrite (Carrucio, 1968). One would then expect that were leaching of material from the abandoned mines having a significant effect on the water composition there would be an increase in the concentration of iron downstream and certainly a difference in concentration between those samples collected above the mines and those below. It would also be expected that the PH should show a downstream increase. In examining these values, there does appear to be an increase in PH and iron though the values are not entirely consistent. Using the Mg/Ca ratio as an indicator of increasing concentration downstream (Ca and Mg have a 92% correlation) the correlation between this ratio and iron concentration is 72% and the correlation between iron concentration and PH is 82%. Though the correlation is far from perfect, a trend does seem to be indicated. It therefore seems that if leached material from the mines is still presently affecting the water composition it is doing so to a very minor if not questionable degree.

In addition to the four elements tested for and previously mentioned, atomic absorption tests were made for the toxic metals cadmium, lead and mercury. All standards were prepared following the instructions outlined in the Perkins-Elmer manual for atomic absorption.

Mercury is found in very few natural waters though the element may be introduced into water through the disposal of metallurgical or other industrial wastes (Hem, 1970). Testing of the samples for mercury concentrations revealed no detectable amounts. In the Avella area there is no heavy industry at the present time disposing of waste material in the creek drainage area.

The abundance of cadmium in natural water is about that of mercury. Cadmium can be introduced though since it is sometimes used as a plating metal in industry. In testing the samples for this element many difficulties were encountered as the tube was rather old. Acontinual adjustment of the gain was necessary causing a very irregular fluctuation in the graph. This was further complicated by a high degree of "noise". It soon became apparent. though, by visually observing the recording process, that no detectable concentrations of cadmium were being recorded.

Lead is more commonly present in natural waters than either cadmium or mercury but is found in concentrations that are very low. In testing for this element some of the samples showed evidence of the presence of lead but the peaks were so small as to make it impossible to calculate concentration. Other samples showed no evidence of lead at all. It seems that if a more quantitative determination of lead is to be made, further research will be necessary.

Coal	No. of Samples	Acid-Producing Potential			Coefficient Of Variation (CV%)
		High	Low	Avg.	
Washington	4	36.17	5.32	17.12	82.73
Waynesburg	4	20.90	12.56	16.53	21.52
Uniontown	2	6.90	6.53	6.72	3.90
Redstone	4	14.52	7.27	10.64	31.65
Pittsburgh	12	2,497.52	691.9	1,086.77	55.16
Elk Lick	2	6.71	5.74	6.22	11.05
Harlem	4	14.50	5.46	8.60	46.81
Bakerstown	20	268.42	39.16	101.69	72.05
Brush Creek	2	9.18	8.62	8.90	4.45
Upper Freeport	22	2,005.99	129.0	525.97	91.64
Kittanning	4	7.06	4.04	5.33	23.87
Lower Mercer	2	7.87	4.90	6.38	32.79
Cedar Grove	2	2.83	2.42	2,62	11.04
#2 Gas	2	9.76	5.00	7.38	45.61
Sewell	2	8.91	8.70	8.80	1.69
Pocahontas #3	2	8.39	6.37	7.38	19.36
"Peacock" (stratigraphic position unknown)	2	8.01	6.61	7.31	13.59

Table 3

Summary of acid-producing potential from acid leaching experiments (Renton, Hidalgo, 1973)

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